Sediment Handling at Indrawati III's settling basin, Nepal

Javier Zamora
Project Engineer
SEDICON LATINOAMERICA
San José, Costa Rica

Tom Jacobsen
Technical Director
SEDICON AS
Trondheim, Norway

Introduction

The 7,5 MW run-of river hydropower plant Indrawati III in central Nepal was facing severe sediment problems until 2017. During monsoon, sediment depositions in the settling basin lead to frequent shutting down of the power plant in order to remove the sediments.

In 2017 the owner procured two innovative systems to handle the sediment income in the settling basin of the project: The SediCon Sluicer, a fixed system on the bottom of the settling basin, and the SediCon Dredge, a movable suction head that allows sediment removal at any location of the settling basin.

The systems were installed and commissioned in July 2017, displaying an impressive sediment removal capacity of more than 2,000 ton sediments per hour for the two SediCon Sluicers combined and 105 ton of sediments per hour for the SediCon Dredge.

1. Background

Indrawati III is run-of-river hydropower plant located in Sindhupalchowk District, Nepal. The project was commissioned in 1999 and it is owned and operated by National Hydro Power Company (NHPC). It uses the water from the Indrawati river, located in Bagmati zone, the Central Developed region of Nepal. The location of the project can be found in Figure 1.

Fig. 1 Location of Indrawati III HPP (Source: Google Earth, 2017).

The catchment of the Indrawati river is originated in the Himalayan region, at an elevation of almost 3,500 m a.s.l., while the intake of Indrawati III is located at approximately 920 m a.s.l. Rainfall and snowmelt are the main components influencing the river flow. The snowmelt is generated during summer in the upper part of the catchment and the rainfall has an annual average of approximately 2,800 mm. These two factors intensify the river flow during monsoon period, which happens between May and October.

The main activity in the catchment of Indrawati river is agriculture, with 32.8% of the catchment area[1]. Therefore, the uses of the water are mainly irrigation, water mills and drinking water. During the last years there has been a development of micro and small hydropower. Within this catchment, after the confluence of the Indrawati river with Lapse river, one can find the intake of Indrawati III Hydropower Plant.

Indrawati III HPP has a capacity of 7.5 MW with an annual production of 50 GWh, a net head of 65 m and a discharge of 14 m^3/s. The run-of-river intake takes the water into a 100 m long settling basin. After the settling basin there is a 3-km tunnel leading to the power house, which is equipped with 3 Francis turbines.

The project headworks consist of a low height weir that derives the water into the one-chamber settling basin. The intake has a guiding wall and a bottom gate to flush gravel and rocks that are deposited in front of the intake during floods. There is a trash rack that avoids the entrance of sediments higher than 50 mm, and the settling basing all the retains particles larger than 0,3 mm. The settling basin was designed with a free flow flushing system, which had to be frequently used, interrupting the water supply and hence the energy production. Figure 2 shows the general arrangement of the headworks.

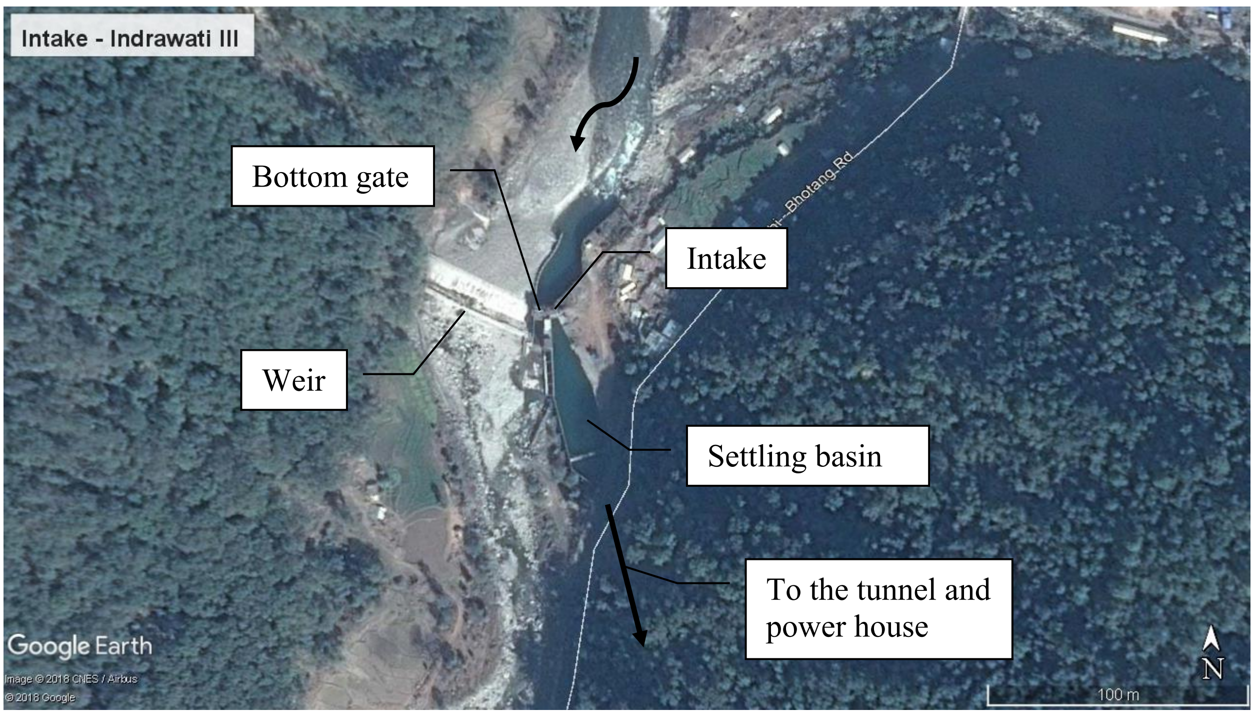

Fig. 2 Indrawati III Headworks (Source: Google Earth, 2017).

2. Sediments in Indrawati III

Considering the characteristics of the catchment, a large sediment yield can be expected. The steep slopes and the land use mainly focused on agriculture, combined with the snowmelt and heavy rain during monsoon periods generate a large amount of sediments than can be transported by the river.

External factors have influenced the sediment yield. The most recent event was the Earthquake on April 25th, 2015, which produced some minor damages in the hydropower plant. Despite the power plant could keep running after the earthquake, the natural event produced several landslides along the river, substantially increasing the potential sediment load and hence, increasing the sediment yield during the next months and years.

2.1 Sediment challenges

Since the project started operation, the sediment yield has been higher than expected. The sediments have been affecting the operation of the power plant and increasing maintenance costs. The power plant was facing different consequences due to the sediment yield, such as large deposition in the settling basing, an inefficient flushing system, scouring of the weir and other structures, and turbine wear.

The severe sediment deposition in the existing settling basin occurs during monsoon periods when heavy sediment loads are brought by the river. The intake has only one settling basin, which means that it was required to stop the power production every time that the sediments in the settling basin had to be removed.

Besides the constant requirement of flushing, the flushing system had not enough capacity to remove all the deposited sediments. Due to the wide shape of the settling basin and the low slopes of the hoppers, the free-flow system could remove only a percentage of the sediment volume. Labor was frequently required to manually mobilize the sediments into the central channel and out of the settling basin.

Large amounts of coarse sediments are also carried out by the river during monsoon periods as bed load. This material normally goes over the weir or through the undersluice gate, staying away from the settling basin. Nevertheless, this bed load is producing heavy scouring in the weir, the undersluice and the bottom slabs at the project headworks.

As the settling basing is swiftly filled up with sediments and the flushing system was not working properly, particles larger than allowed were entering the tunnel and reaching the turbines. Such particles were wearing the turbine runners, reducing the power plant efficiency and increasing maintenance costs. Figure 3 illustrates the sediment consequences.

a) Sediment deposition prior to installation of SediCon Sluicer (Source: NHPC)

b) Inefficient flushing system (Source: NHPC)

c) Scouring at Indrawati III headworks

d) Wear of a Francis turbine, Chile

Fig. 3 Sediment consequences in the hydropower plant.

2.2 Solution

Renovation works were done to the Power Plant during the beginning of 2017. As part of this works, new sediment handling solutions were installed in the settling basing. The supplied systems are two SediCon Sluicers and one

SediCon Dredge. The Sluicer is a fixed system of slotted pipes in the bottom of the settling basin, while the dredge is a suction pipeline floating on the settling basin, with a suction head that is operated from a small raft.

Both systems work by hydrosuction, i.e. using only the water head between the water level and the discharge as a driving force. The discharge is normally regulated by a valve. When the valve is opened, the water column creates a flow inside the pipeline system, which is designed to suck the sediments into the pipeline and out of the desilting basing.

2.2.1 SediCon Sluicers

A SediCon Sluicer is a sediment removal system especially designed for settling basins and tunnel sand traps. The Sluicer system at Indrawati III consists of two units in the sedimentation basin (Fig. 4). The sediments removed from the system are transported from the settling basin in outlet pipes, which passes through the walls towards the discharge point. The water-sediment flow is controlled by valves located at the outlet pipe.

The system has 4 main components: 1) The slotted pipes, installed inside the desilting basing, 2) The outlet pipes, going from the desilting basin back to the river, 3) The SediCon Units, which is an especially designed connection between the slotted and the outlet pipes, and 4) the outlet valves. The sediments enter the pipes through the slots located under all the pipes inside the settling basin and are transported out and back to the river through the outlet pipes.

The main benefits of the Sluicer are:

- High Capacity and low water consumption.
- Sediments can be removed at any time without interrupting the water supply.
- The outlet valve is the only movable part.
- Removes all types of sediments.
- Environmentally friendly.

Fig. 4 SediCon Sluicer at Indrawati III

2.2.2 SediCon Dredge

The Dredge is a sediment removal for reservoirs or wide settling basins. The main components of the system are: 1) one suction head, 2) a small raft to operate the suction head, 3) a water jetting system to break the sediment compaction and cohesivity, 4) the suction hose floating on the settling basin, 5) a siphon going out of the settling basing, and 6) the outlet valves.

The suction head is operated from a small raft. The suction head has a water jetting system to break the cohesive sediments and it is connected to a suction hose which transports the sediments through the siphon, over the wall to the discharge point, discharging the sediments back to the river.

The benefits of the dredge are:

- Ensures high capacity and easy operation.
- Requires low investment and operation cost.
- Operation of the system does not affect power plant operation.
- Environmentally friendly solution.
- Removes all types of sediments, from rocks to clay.

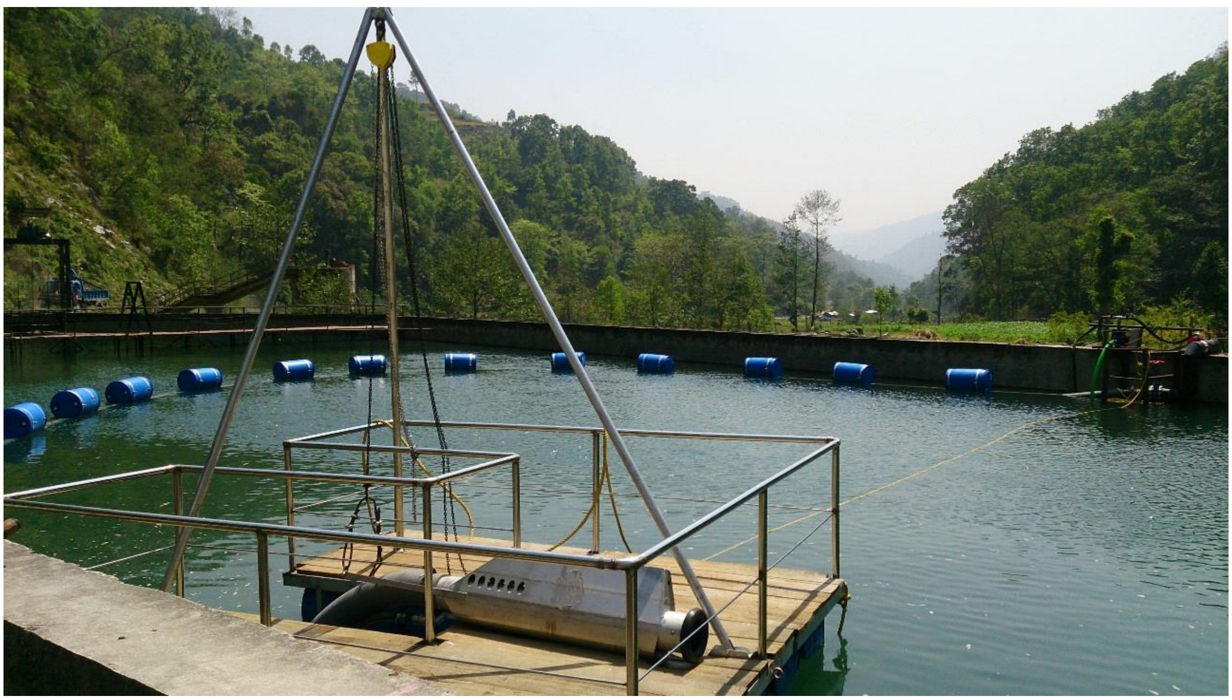

Fig. 5 SediCon Dredge at Indrawati III

3. Testing, challenges and current situation

The installation of the two systems was done during April of 2017, before the monsoon season. After installation and commissioning, the power plant re-started operation. After two months of monsoon, when there were enough sediments in the settling basing, the efficiency tests were performed. The objective of testing is to obtain the sediment removal capacity of both systems, in tons of sediment removed every hour (ton/h). The capacity is obtained by measuring the discharge, based on measured length and outlet angle of the water jet, and the sediment concentration, based on weight of dry samples.

Measured capacities of the Sluicers were 1,480 ton/h for the unit 1, which is more than one barrel of sand every second (Fig. 6) and 690 ton/h for the unit 2, for a total of 2,170 ton of sediments per hour. The difference between the capacities of the units is probably due to less sediments above unit 2 and hence not ideal conditions for testing. The real capacity of unit 2 should be similar to unit 1 once the same level of sediments above the unit is reached.

The water consumption was 2,400 m^3/h for the unit 1 and 2,500 m^3/ h for unit 2, giving a total of 1.36 m^3/s. This discharge seems to be roughly 10% of the power plant discharge, but it happens only during the flushing operation, which only takes place a fraction of the time. The actual volume of water for flushing is less than one percent of the power plant discharge or even zero, if the flushing is done when there is surplus water, like shown in Figure 6. As one can expect, the size of the sediments removed from the unit 1 (upstream) is larger than the sediment from unit 2 (downstream). The d_{50} was 0.22 mm for unit 1 and 0.17 for unit 2.

Fig. 6 Discharge from SediCon Sluicer unit 1, 1,480 ton of sand per hour. The discharge of sand equals well above one barrel of sand every second.

After commissioning, during the monsoon, the Sluicer unit 1 showed a reduced discharge of clean water only (no sediments). It was found out that the trash rack was damaged, resulting in entrance of gravel and rocks into the settling basin. The gravel created a filter, preventing sand from entering the slotted pipes and affecting the correct functioning of the SediCon Sluicers. Besides, some large rocks entered the pipeline, partially blocking of system. SediCon Sluicer unit 2 was functioning throughout the entire monsoon.

To solve the problem the debris was removed from the system and the trash rack was repaired. This was done after the monsoon. After the modifications, the system has been successfully removing the sediments that are constantly deposited in the settling basing, without interfering the power plant operation. Moreover, during 2018’s monsoon, Indrawati III HPP has faced the highest sediment income in the last 10 years, while the power plant was running without any shut down for sediment removal. The increased revenue due to continuous power production, less turbine maintenance and increased runner efficiency has already paid the investment in SediCon Sluicers and SediCon Dredge.

4. Conclusions

Indrawati River has a large sediment load which has affected the power plant since it started operation. the consequences of inadequate sediment removal facilities have been costly due downtime, maintenance and reduced runner efficiency.

Even though some challenges were faced, the SediCon systems were successfully installed and have substantially improved the sediment handling capacity of the settling basin.

Sediments can now be removed without interrupting the power plant operation and for the first time the power plant could produce continuously through the monsoon period, reducing maintenance costs and increasing revenue of the power plant.

References

1. **Karky, A.**, “Indrawati River Basin Study”, *Consolidated Management Services Nepal*, 2005.

The Authors

Javier Zamora. Graduated in Civil Engineering from the University of Costa Rica (UCR) and with a master's degree in Hydropower Development from the Norwegian University of Science and Technology (NTNU). Project Engineer at SediCon, company specialized in sediment handling for hydropower plants. He is involved in the design, delivery and installation of SediCon Systems in different projects all over the world.

Tom Jacobsen. Graduated in Hydraulic engineering from NTNU, the University of Science and Technology in Trondheim, Norway in 1990. He then worked for a construction company Skanska for two years. In 1997 he defended his doctoral thesis “Sediment Problems in reservoirs – control of sediment deposits”. From 1999 and onwards has been working for the Norwegian company SediCon as consultant, developer of sediment handling technologies and with implementation of sediment removal projects both offshore well as for hydropower projects.